Substrate Temperatures Influence Root and Shoot Growth of Southern Highbush and Rabbiteye Blueberries

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Abstract. A greenhouse study was conducted to evaluate the influence of substrate temperatures (16, 27, and 38C) on root and shoot growth of six blueberry (*Vaccinium* spp.) clones (three clones each of two types). Between types, southern highbush (primarily *V. corymbosum* L.) produced more roots and total growth than rabbiteye (*V. ashei* Reade). Comparing clones, 'Gulfcoast' (southern highbush) was the most vigorous and 'Tifblue' (rabbiteye) the least vigorous. Each clone had a negative linear response to substrate temperatures in all growth characteristics. Root and shoot growth was best at 16C. This study indicates that both rabbiteye and southern highbush blueberries would respond favorably to cultural practices that lower soil temperatures during the summer growing season.

Blueberries have a fine, fibrous root system that is relatively shallow and devoid of root hairs (Eck, 1988). Abbott and Gough (1987) reported that roots of highbush blueberries grew throughout the year, but growth was greatly reduced in soil below 8C. They found two periods of accelerated growth, the first in early June and the second in September. These periods occurred when soils were between 14 and 18C, and root growth declined at soil temperatures below or above this range.

In a greenhouse study, Basiouny and Powell (1985) found that high (50C) soil temperatures enhanced the early shoot growth of young 'Tifblue' rabbiteye blueberries, but growth rate leveled off or ceased after ≈2 months. Abbott and Gough (1987) reported that highbush blueberry maximum shoot growth coincided with the period of maximum root growth.

Mulching reduces weed growth, helps maintain uniform soil moisture, promotes better soil structure, reduces soil erosion, and lowers soil temperatures in the summer (Darrow, 1957). Organic mulching lowered soil temperature at 15 cm below the soil surface ≈6C during the summer in southern Mississippi (Magee and Spiers, 1995). In rabbiteye blueberries, the major factor influencing root distribution in a sandy, well-aerated soil was soil moisture (Spiers, 1986). Incorporating peatmoss in the planting hole tended to concentrate roots near the crown area and at depths of 30 to 40 cm. Mulching tended to concentrate the roots in the upper 15 cm of soil and resulted in more uniform root distribution from the crown outward. A commercial highbush blueberry planting in Arkansas yielded better when continuously mulched rather than

mulched only 1, 2, or 3 years after planting (Moore and Pavlis, 1979).

Southern highbush blueberries, hybrids of *V. corymbosum* with primarily *V. darrowi* Camp and other species such as *V. ashei* (Lyrene, 1990), grow more vigorously and produce higher yields when mulched with organic materials than when unmulched (Clark and Moore, 1991). Spiers (1992) found mulching had a more positive influence on plant growth and yield of southern highbush blueberries than irrigation or incorporated peatmoss. When grown under similar cultural and environmental field conditions, rabbiteye blueberry plants had larger root and shoot biomass and plant volume and higher fruit yield than southern highbush plants (Makus et al., 1995).

The purpose of this study was to determine the influence of substrate (growth medium) temperature on the root and shoot growth of rabbiteye and southern highbush blueberries.

Materials and Methods

Southern highbush and rabbiteye blueberry rooted cuttings were transplanted into 4-liter pots in Spring 1991 and grown outside with uniform cultural practices through the summer. Fifteen plants each of three clones of southern highbush (MS132, 'Magnolia', and 'Gulfcoast') and rabbiteye ('Climax', 'Premier', and 'Tifblue') were moved into a greenhouse (14-h daylength, air 16 ± 3C) in September. In early November, plants were removed from pots and the medium was washed from the roots. Measured from the crown, roots were pruned to 12 cm and tops removed at a height of 18 cm. Plants were placed in 56-cm (width) × 152-cm (length) × 20-cm (depth) aboveground beds. Each bed contained a thermostatically controlled heating mat (Pro-Grow Corp., Brookfield, Wis.) and 1 pine bark : 1 sand : 1 peat medium (by volume). Treatments consisted of three substrate (bed) tempera-

tures (16, 27, and 38C) as main plots replicated five times and three clones each of two blueberry types as subplots with single-plant experimental units. These six plants (one plant/clone/type) were uniformly spaced and randomly placed within each bed.

Greenhouse air temperatures from treatment initiation on 19 Nov. 1991 until late Mar. 1992 averaged 16 to 18C, with a range of 14 to 24C. Throughout the study, substrate temperatures (10-cm depth) for the three treatments ranged as follows: 16 ± 2, 27 ± 3, and 38 ± 3C. By the last of March, air in the greenhouse could not be maintained in the 16 to 21C range, and the experiment was terminated on 6 Apr. 1992. During the study, plants were uniformly fertilized twice weekly using a water-soluble solution containing: 1 μM each of N, K, and Mg and 2 μM of Ca plus minor elements. Additional watering was applied as needed to beds maintained at the higher temperatures. Data were analyzed by general linear models procedure (SAS Inst., 1985).

Visual ratings (0 = dead; 1 = worst, but living; 5 = best plant) for plant shoot vigor were taken 3 days before study termination. At termination, plants were removed from the beds and their roots were washed. Roots were visually rated for vigor using the above system and root length (longest) was measured. New top and root growth were removed at the site of the original pruning, dried (60C), and weighed.

Results and Discussion

Substrate temperatures significantly ($P > 0.001$) influenced shoot, root, and total plant growth; root length; and root and shoot vigor ratings (Table 1). No interactions that included temperature as a factor were significant.

All growth measurements decreased linearly as substrate temperature increased (Table 2). Shoot growth (dry weight) doubled with a decrease in substrate temperature from 38 to 27C and increased 1.5× with a decrease from 27 to 16C. This relationship corresponded to shoot vigor rating increases of 2.3× and 1.4×, with a decrease in temperatures from 38 to 27C and then to 16C, respectively. Shoot growth was more than 3× greater with a substrate temperature at 16C than at 38C.

Root growth (dry weight) increased 1.3× with a decrease in substrate temperature from 38 to 27C (Table 2). Between 27 and 16C, root weight increased 1.6×. With substrate at 16C, root growth was twice that at 38C. Visual root vigor ratings were closely related to dry weight measurements. Root length followed the same relationship with substrate temperature as did dry weight and visual vigor ratings, but with less dramatic differences. As media temperatures decreased from 38 to 16C, root length increased 1.6×.

Shoot growth, as measured by dry weight, was similar for southern highbush and rabbiteye blueberries (Table 2) but did differ significantly between clones (Table 3). 'Gulfcoast' and 'Climax' had the most shoot growth and that of 'Gulfcoast' was significantly higher than for all other cultivars, except 'Climax'. Shoot growth of 'Climax' was significantly

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Table 1. Significance of growth differences in blueberries (F value probability) due to substrate temperature (T), type (S), and clones within type [C (S)].

Source of variation	df	New growth (dry wt in g)			Root length (cm)	Vigor rating ^z	
		Shoot	Root	Total plant		Shoot	Root
T	2	***	***	***	***	***	***
S	1	NS	***	***	NS	NS	NS
C (S)	4	*	*	*	NS	***	NS
T × S	2	NS	NS	NS	NS	NS	NS
T × C (S)	8	NS	NS	NS	NS	NS	NS

^zVigor ratings: 0 = dead, 1 = worst, 5 = best vigor.NS, *, ***Nonsignificant or significant at $P > 0.05$ and 0.001 , respectively.

Table 2. Influence of substrate temperature on growth of southern highbush (SHB) and rabbiteye (RE) blueberry.

Variable	New growth (dry wt in g)			Root length (cm)	Vigor rating ^z	
	Shoot	Root	Total plant		Shoot	Root
Temperature (°C)						
16	4.8	15.2	20.0	22.8	3.5	4.0
27	3.2	9.7	12.9	20.4	2.5	2.5
38	1.5	7.3	8.8	14.7	1.1	1.4
Linear	***	***	***	***	***	***
Type						
SHB	3.8 a ^y	14.6 a	18.4 a	19.8 a	2.4 a	2.7 a
RE	2.6 a	6.9 b	9.5 b	18.9 a	2.3 a	2.6 a

^zVigor rating; 0 = dead, 1 = worst, 5 = best vigor.^yMean separation, LSD_{0.05}.***Significant at $P > 0.001$.

Table 3. Growth responses of six blueberry clones averaged over all substrate temperatures.

Types ^y	Clones	New growth (dry wt in g)			Root length (cm)	Vigor rating ^z	
		Shoot	Root	Total plant		Shoot	Root
SHB	MS132	2.9 bc ^x	13.0 b	15.9 b	19.1 a	2.5 ab	2.9 a
	Magnolia	3.0 b	11.8 b	14.8 b	21.3 a	2.1 b	2.6 a
	Gulfcoast	5.5 a	18.9 a	24.4 a	18.8 a	2.6 ab	2.7 a
RE	Climax	4.0 ab	9.8 b	13.8 b	20.3 a	2.7 ab	2.7 a
	Premier	3.1 b	7.4 bc	10.5 b	19.2 a	3.1 a	2.9 a
	Tifblue	0.7 c	3.6 c	4.3 c	17.1 a	1.2 b	2.1 a

^zVigor rating; 0 = dead, 1 = worst, 5 = best vigor.^ySHB = southern highbush; RE = rabbiteye.^xMean separation, LSD_{0.05}.

higher than for 'Tifblue' but did not differ from any other cultivar. Under field conditions, 'Tifblue' tends to grow more slowly than other rabbiteye cultivars during the first growing season (John Braswell, personal communication). In this study, shoot growth data and vigor ratings of shoots show this trend.

Root growth (dry weight) differed between types and clones within types (Table 1). Root growth of southern highbush was about double that of rabbiteye blueberries (Table 2). 'Gulfcoast' had significantly more root growth than any other clone (Table 3). 'Tifblue' had less root growth than all other clones but did not differ significantly from 'Premier'. The rest of the clones had about the same amount of root development. The differences found in dry weight measurements were not evident in root length or root vigor ratings.

Total plant (shoot and root) growth of southern highbush was twice that of rabbiteye blueberries (Table 2). 'Gulfcoast' had significantly more and 'Tifblue' produced signifi-

cantly less total growth than any other clone (Table 3).

Root and shoot growth characteristics had high ($P > 0.001$) positive correlations (not shown). These findings are in agreement with those of Abbott and Gough (1987), who found growth of roots in highbush blueberries to be concomitant with shoot growth.

New shoot growth in 'Tifblue' was lowest with the 38C substrate, highest at 27C, and intermediate at 16C. With this exception, no quadratic relationships between plant growth attributes and substrate temperatures were significant.

Substrate temperature had highly significant influence on the shoot, root, and total growth of southern highbush and rabbiteye blueberries. All growth was best in a cool (16C) substrate and growth decreased as temperatures increased. In general, types and clones within types had similar responses to substrate temperatures. 'Gulfcoast', a southern highbush, was the most vigorous clone and

'Tifblue', a rabbiteye, the least. Reported type differences were mainly due to differences between these two clones.

When planted in mineral soils (using incorporated peatmoss and irrigation, but no mulch), southern highbush cultivars are usually less vigorous than rabbiteye cultivars (Makus et al., 1995). In my study, water stress was not a limiting factor. The substrate contained high amounts of organic matter and overall soil and air temperatures were lower than those found during the summer growing season in southern Mississippi (Magee and Spiers, 1995). Shoot growth of southern highbush clones was equal to or greater than that of the rabbiteye clones.

A previous study ranked individual cultural practices according to their production of dry root weight as follows: mulch > incorporated peatmoss > irrigation; plant root weight was correlated positively with plant growth and yield (Spiers, 1986). The present study indicates that the most beneficial influence of mulching on growth of blueberries in the southern United States may be its reduction of soil temperatures during the long, hot growing season. Cultural practices that cause a reduction in soil temperatures apparently promote root and shoot growth in southern highbush and rabbiteye blueberries.

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